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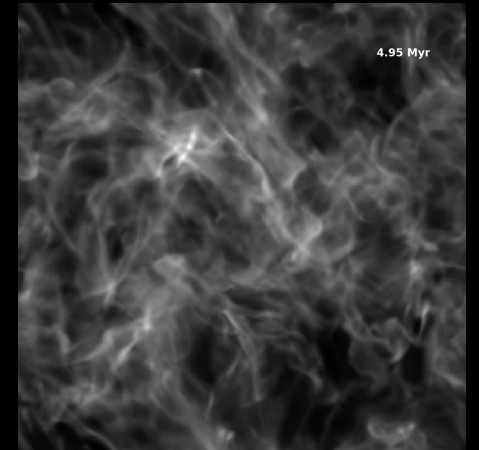
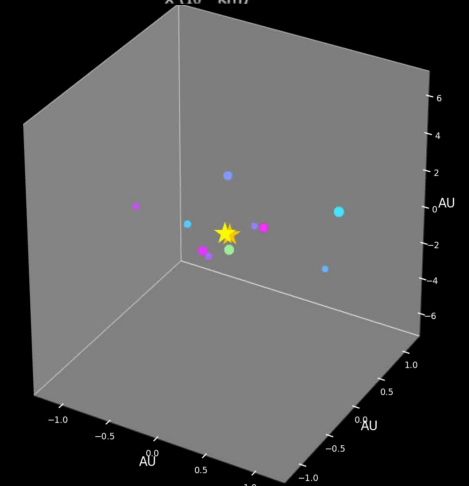
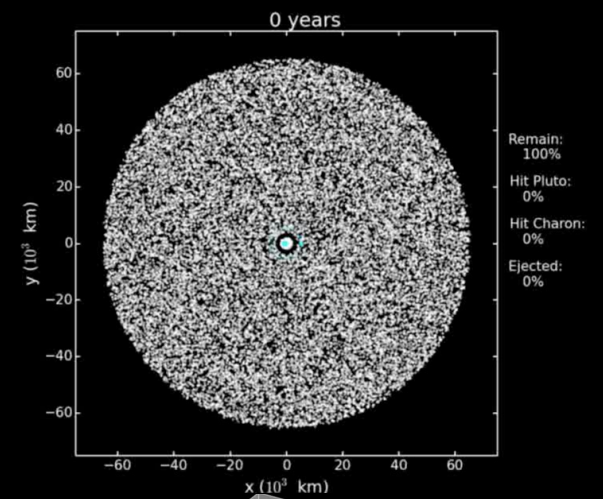
WE ARE MADE OF STAR STUFF

How stars (and planets) are created

Rachel Smullen
LAHS Astronomy Club

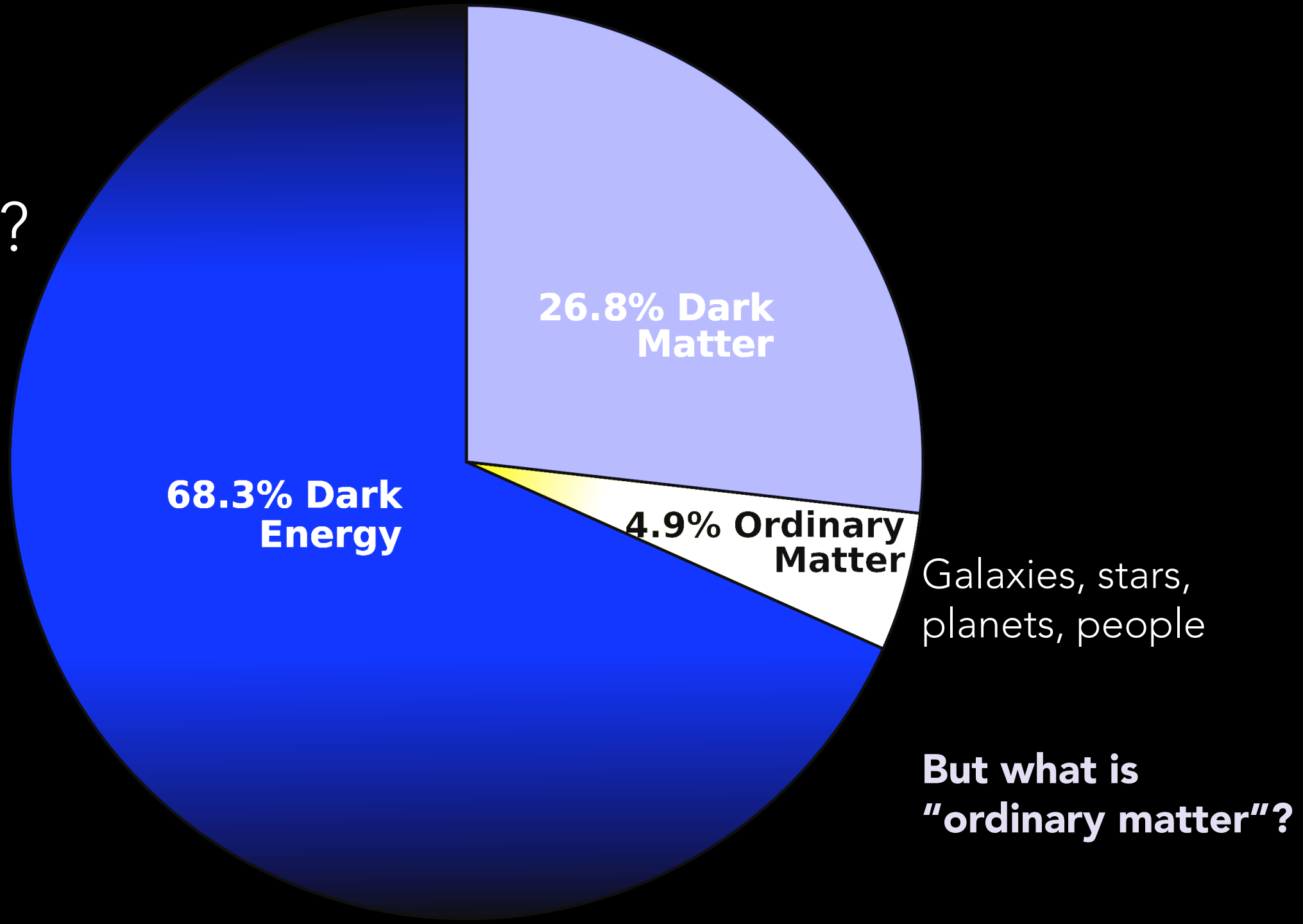
About Me





- Computational (astro)physicist @ LANL
 - I use simulations to study things like
 - Pluto-Charon and the Kuiper Belt
 - Exoplanets
 - Star formation
- PhD from University of Arizona (Tucson) 
- BS from University of Wyoming (Laramie) 
- Hobbies: Books, movies, hiking, travel, cooking, eating...



Stars make up most of what
we see in the universe.

What's in the Universe?



1 H	big bang fusion 						cosmic ray fission 										2 He		
3 Li	4 Be	merging neutron stars 						exploding massive stars 						5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	dying low mass stars 						exploding white dwarfs 						13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr		
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe		
55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn		

Stars are born from giant,
collapsing clouds of gas
(and dust)

The end.

But really, it's just the beginning...



Molecular clouds are collections of mostly hydrogen (plus other stuff) that are floating around in space

But molecular clouds contain a lot of "other stuff" that is important to humans!



We see atoms, molecules, and solid stuff.
Each plays a role in how stars and planets form.

We see things like

- Ammonia
- Formaldehyde
- Water
- Raspberry flavor (ethyl formate)
- Dust
- Ice
- & lots more!



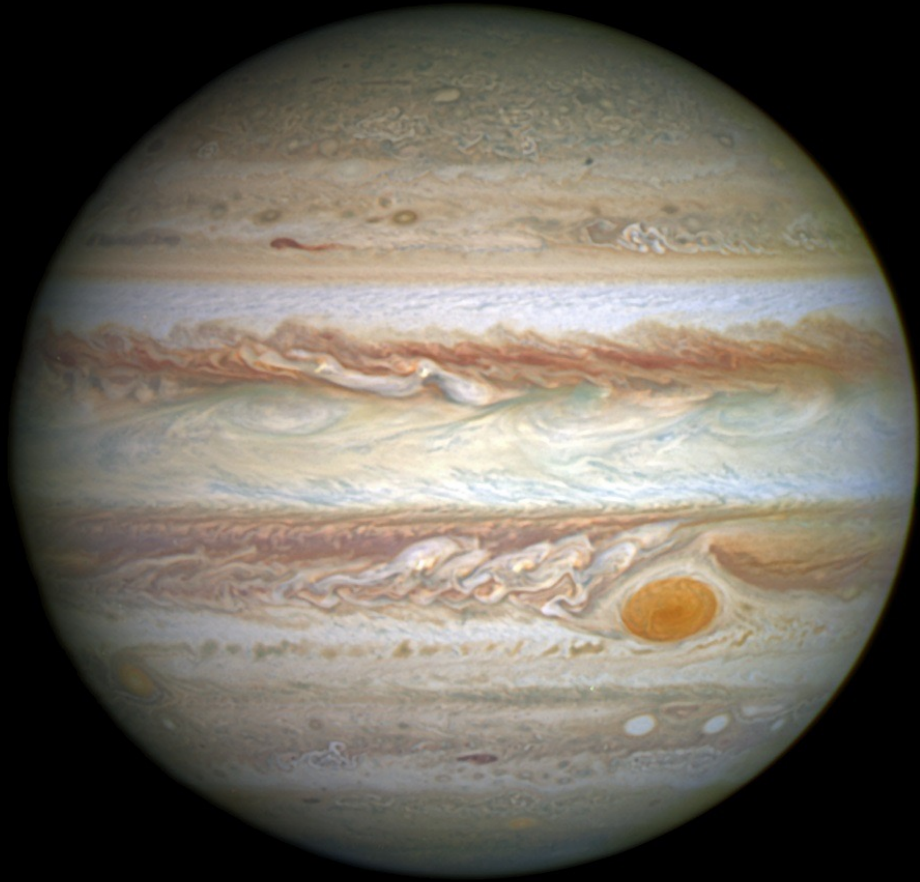
Star formation requires lots of physics working together over millions of years




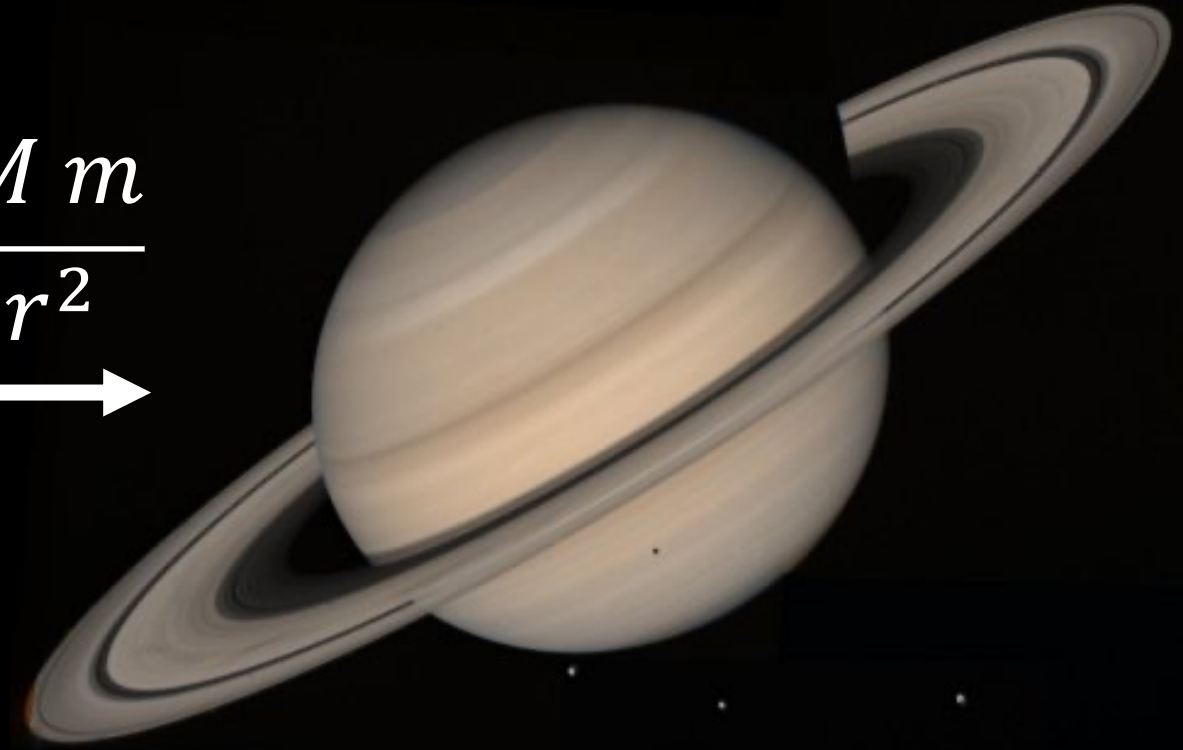
Molecular clouds are where many different physical processes come together. Let's explore!

Image credit: M. Petrasko

Gravity: mass pulls stuff towards itself



$$F \propto \frac{M m}{r^2}$$
A white double-headed arrow pointing left and right, positioned below the equation.

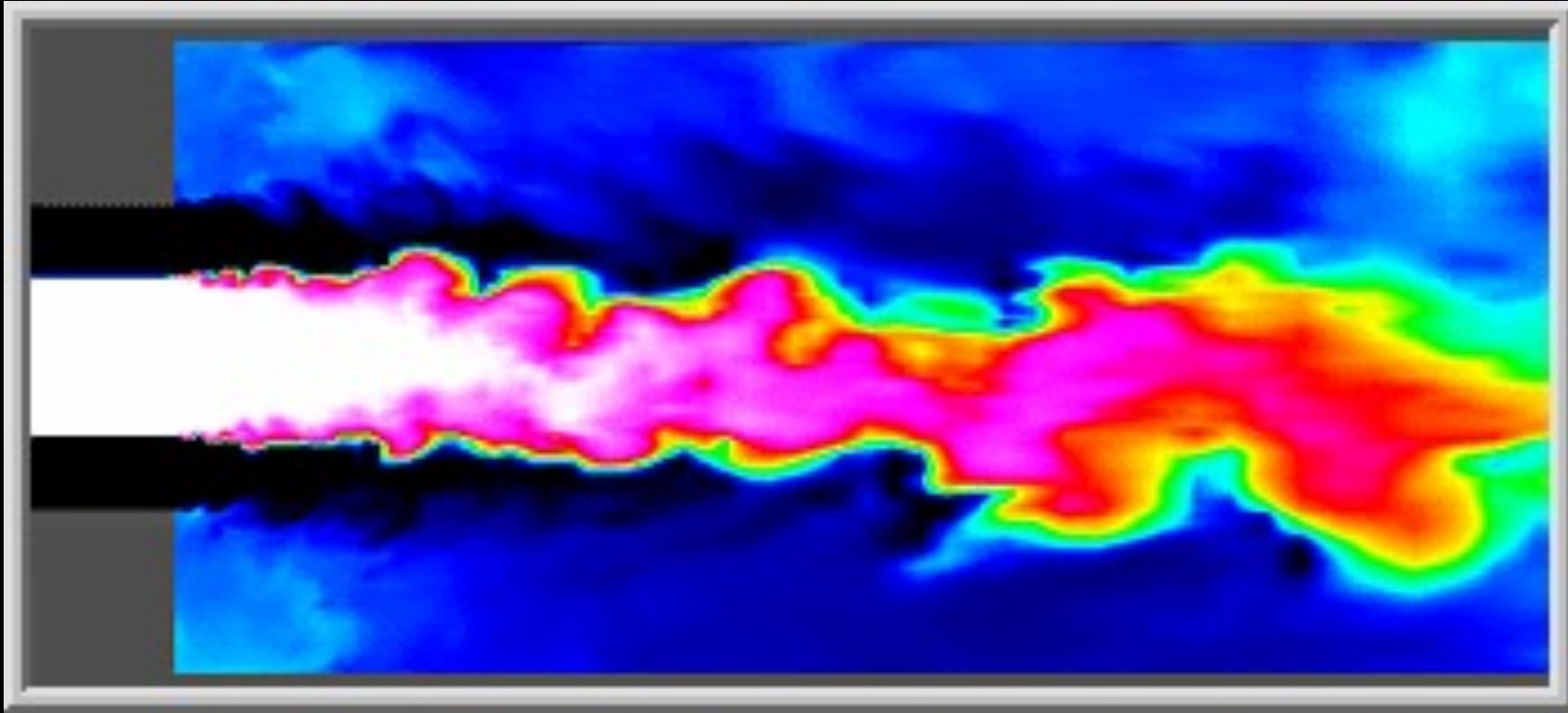


Hydrodynamics: the motion of fluids

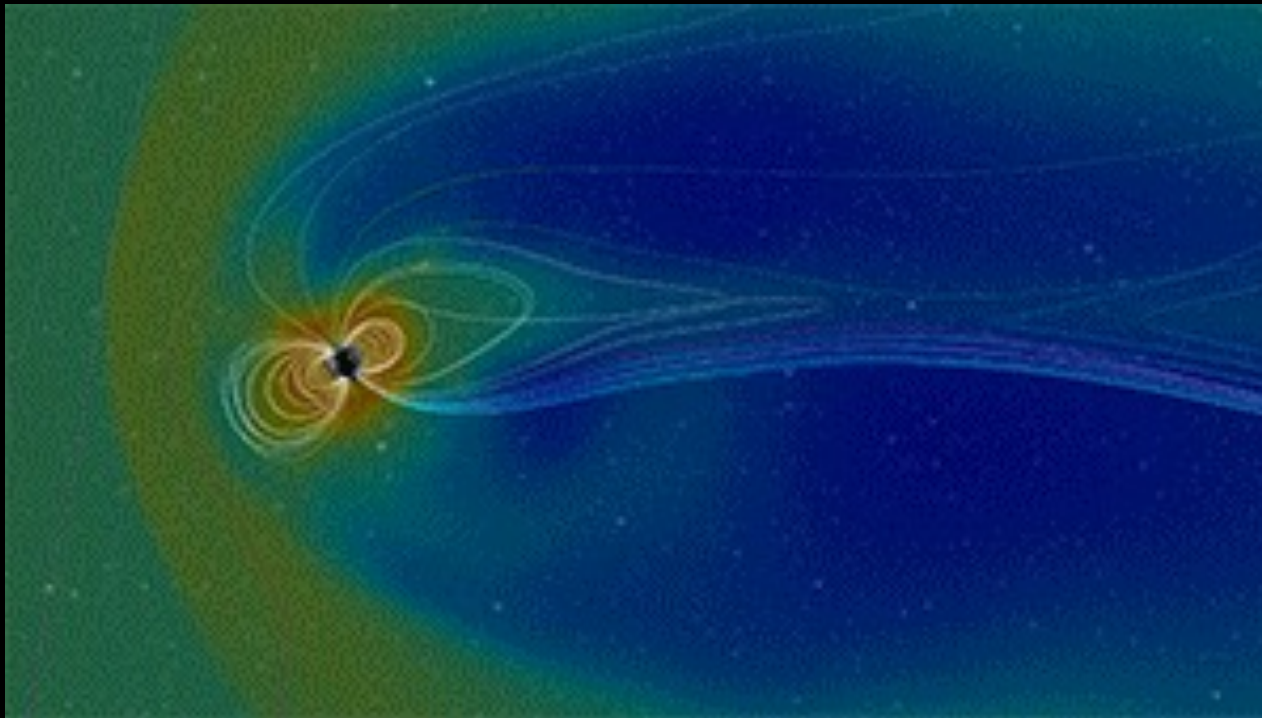


Image credit: M Oblinski

Turbulence: the chaotic motion of fluids



Magnetic fields:
promote or hinder motion in a direction



Radiation: heat gas and make a 'wind'

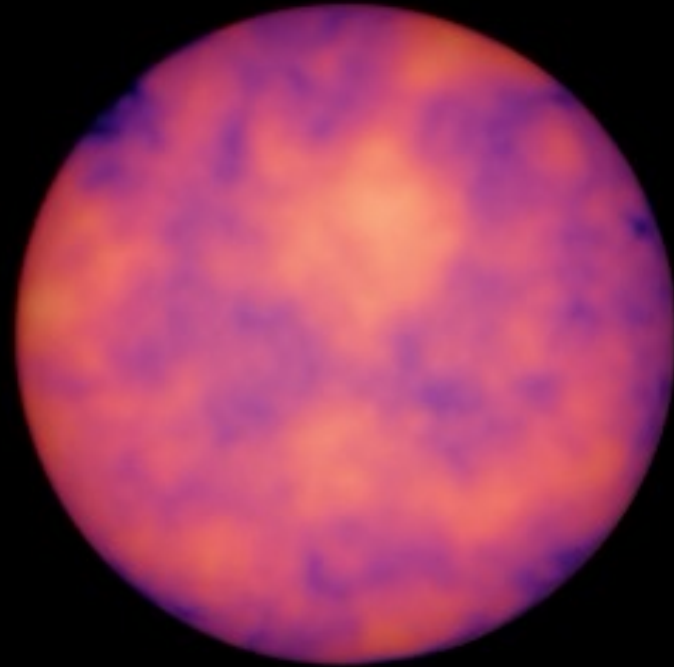
There's also some other processes like chemistry, shocks, etc. that become important later, but we won't cover those today

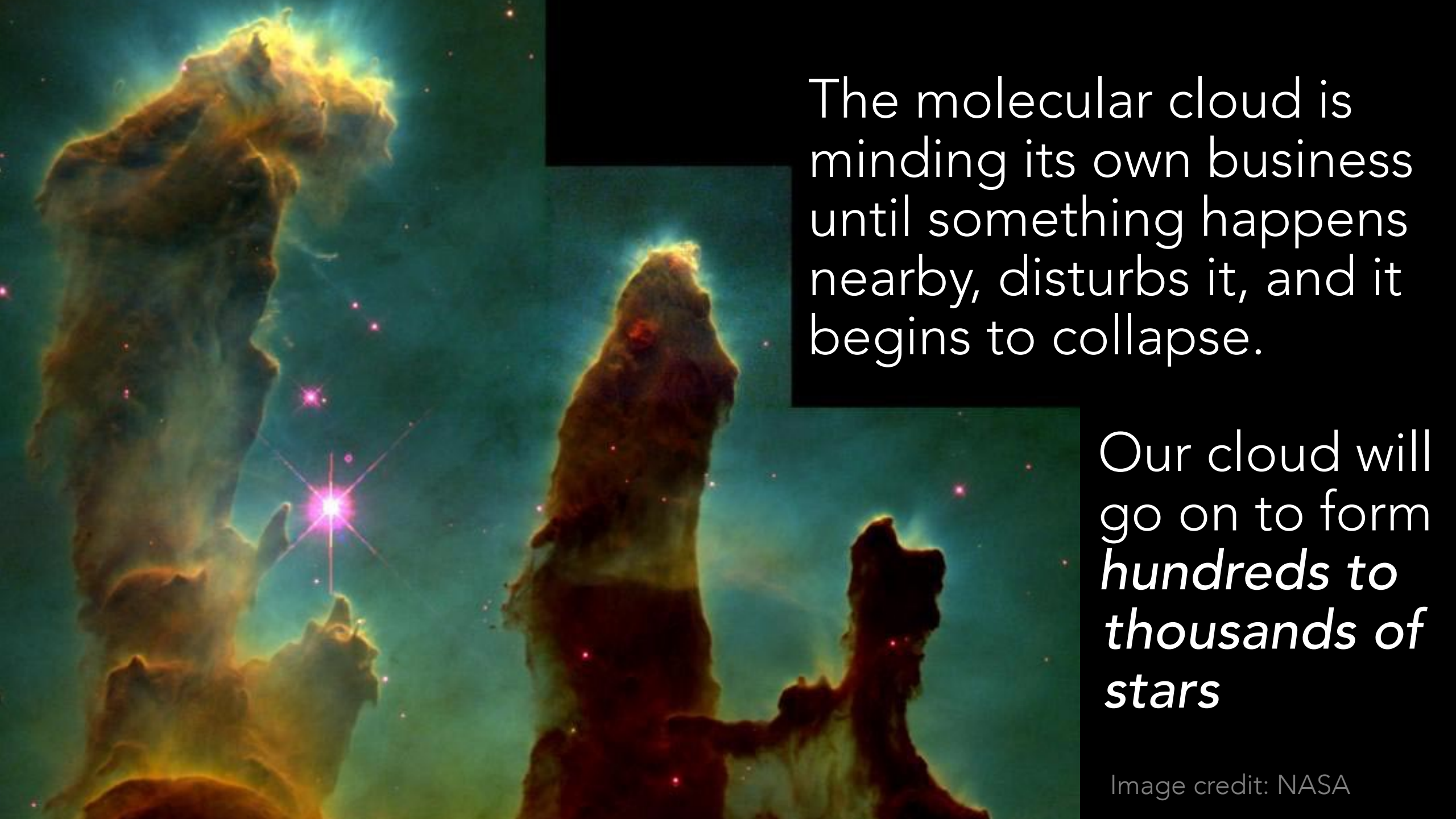
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Putting
it all
together...

0yr

Let's look at the
steps in a little
more detail





The molecular cloud is minding its own business until something happens nearby, disturbs it, and it begins to collapse.

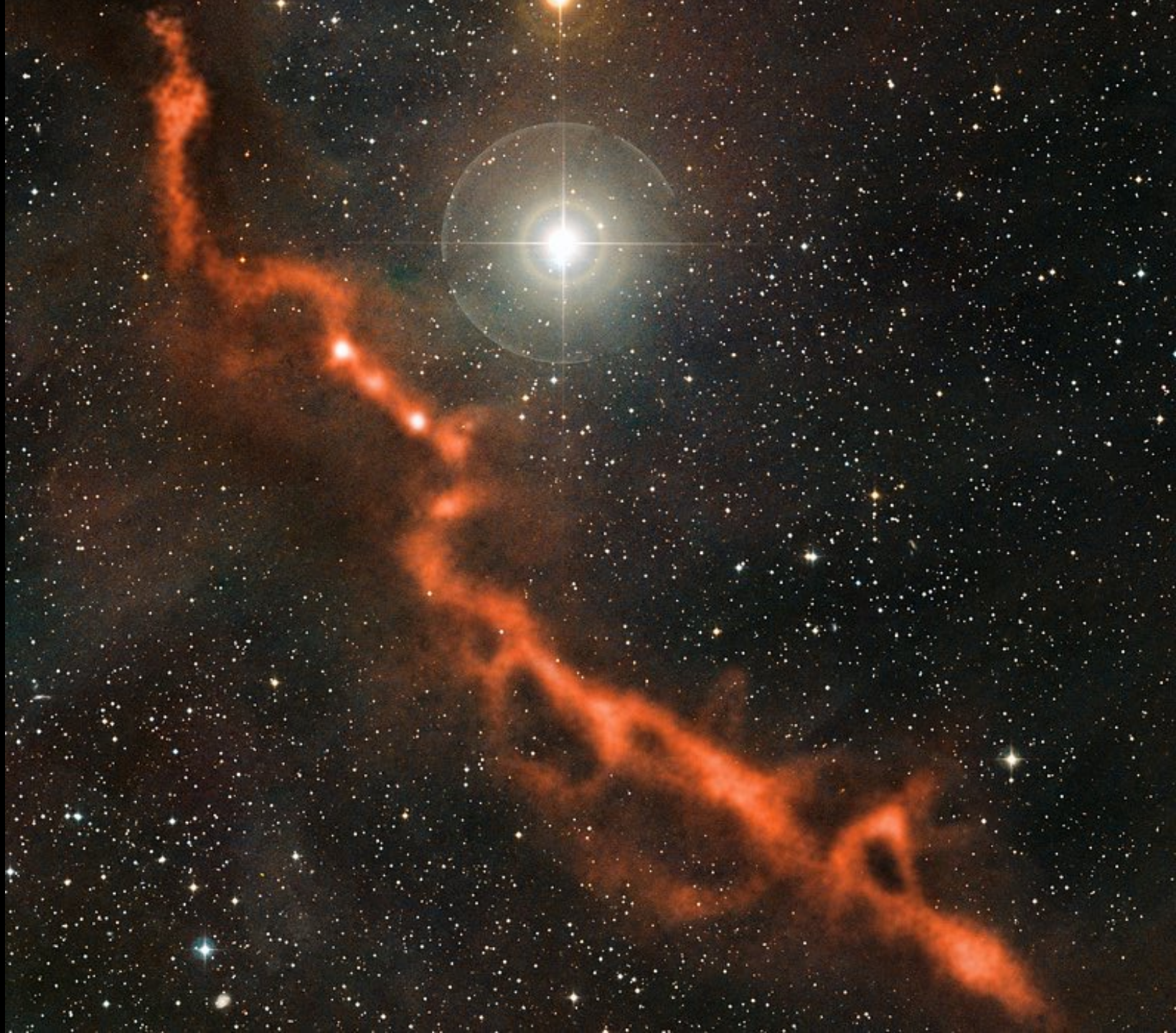
Our cloud will go on to form *hundreds to thousands of stars*

Image credit: NASA

The cloud collapses into *filaments* which then fragment into *cores*.

These cores contain the material from which individual stars form.

Image credit: ESO



The core begins to collapse further down to the center and become very dense and hot.
Because our molecular cloud has some rotation, the inner core flattens out into a spinning disk

due to *conservation of momentum*

Material at the disk center collects to form a *protostar*:
a baby star not yet powered by nuclear fusion

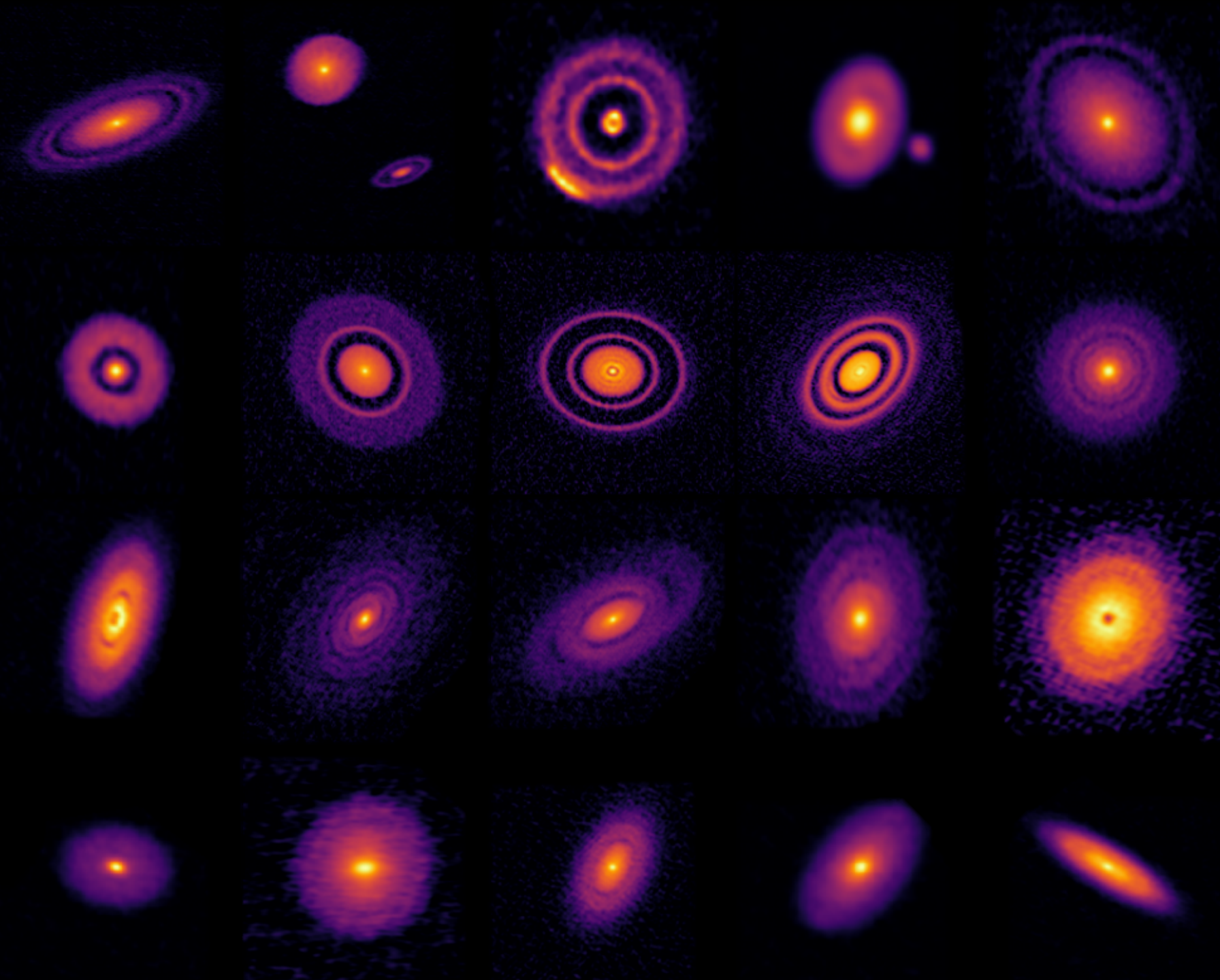


Material *accretes*
onto the growing
protostar.

But not all of the
gas can make it
into the star.

Image credit: ESA





While the star
is growing, its
disk is evolving.

This is when
and where
planets begin
to form

The gas and dust in the star's disk isn't smooth. Planets grow out of clumps of *gas, ice, and dust* in the disk.

The bigger a planet becomes, the more it can grow. Sometimes, planets even leave hints in the disk that they're there.

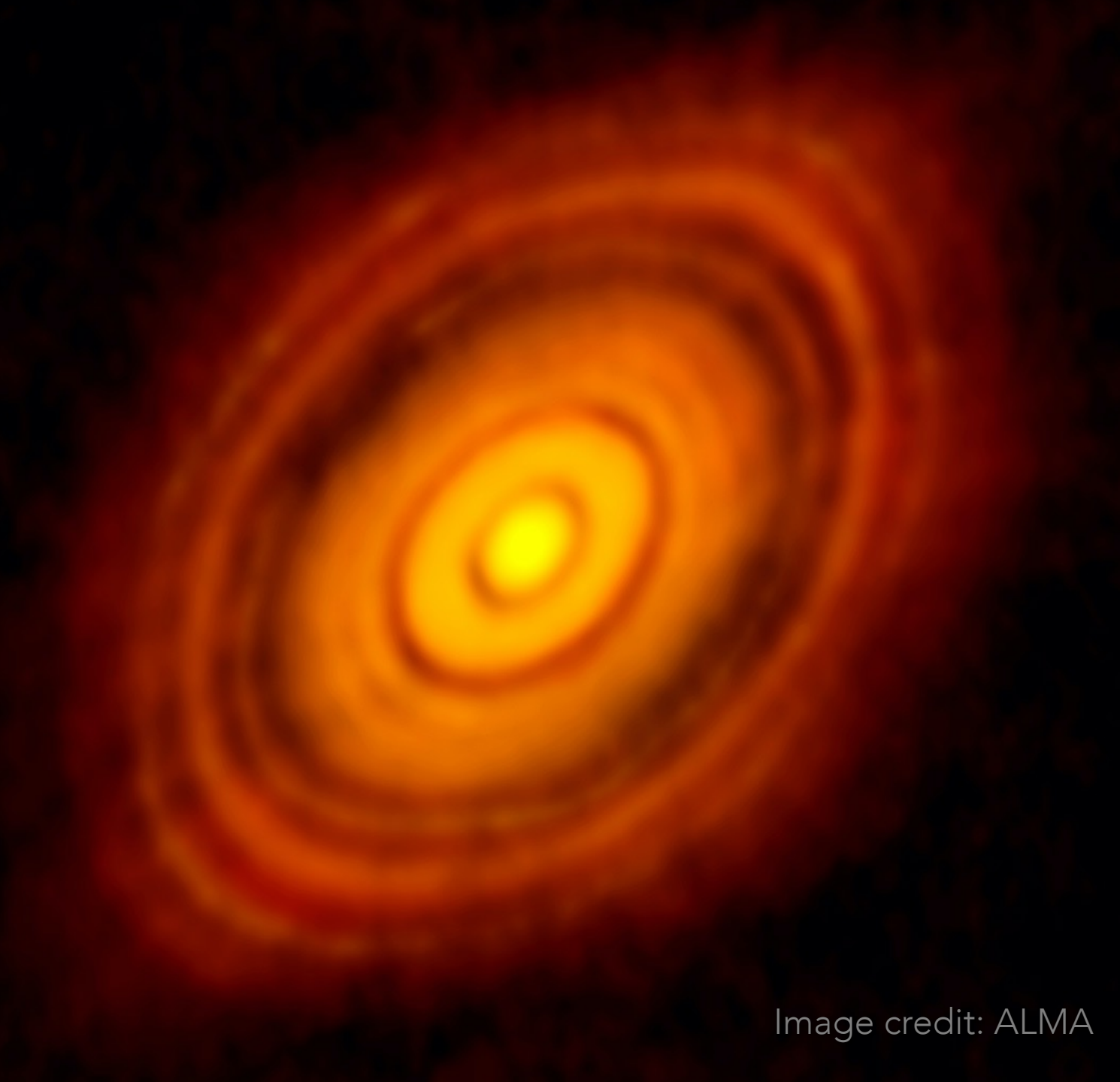
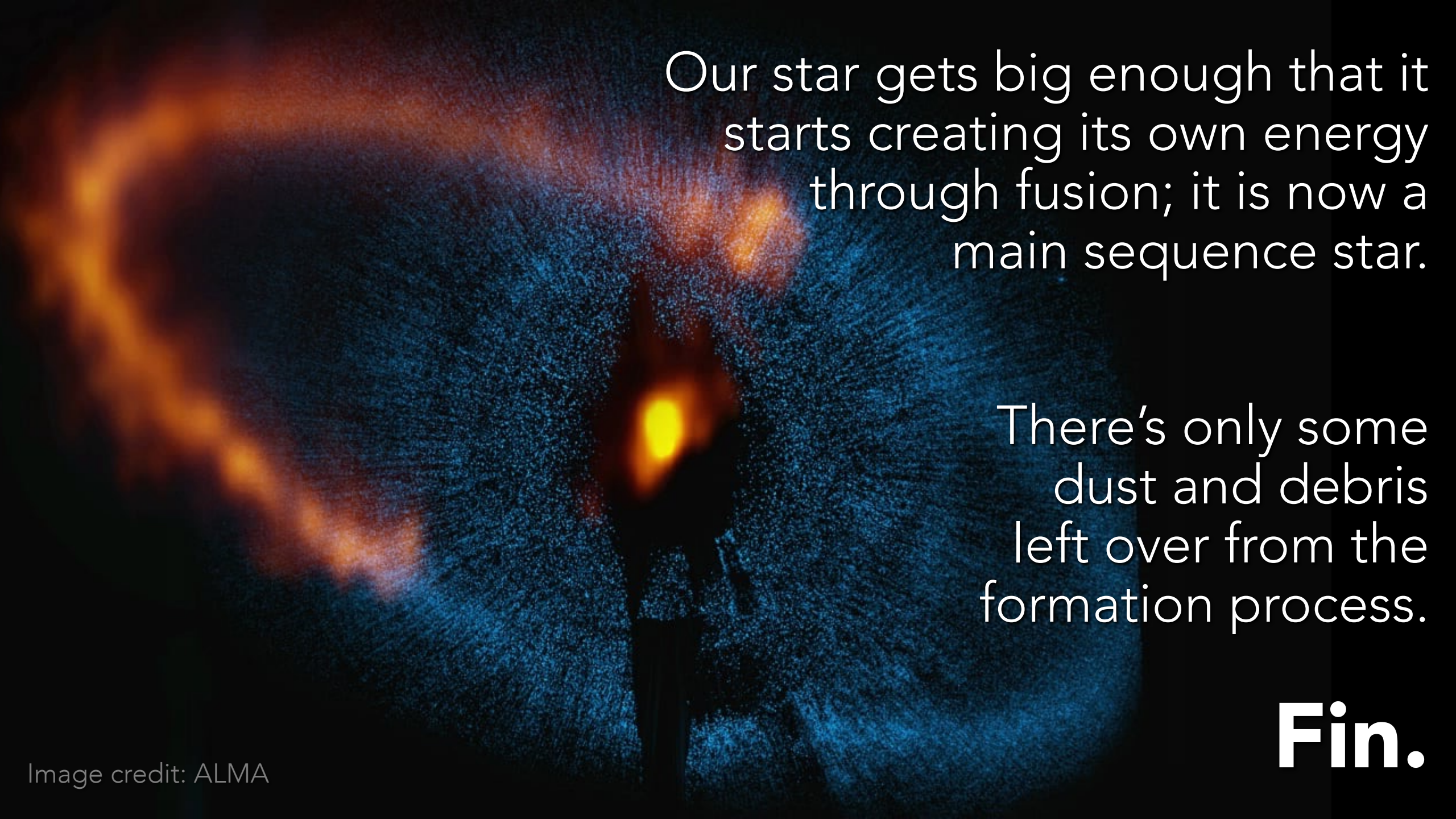


Image credit: ALMA

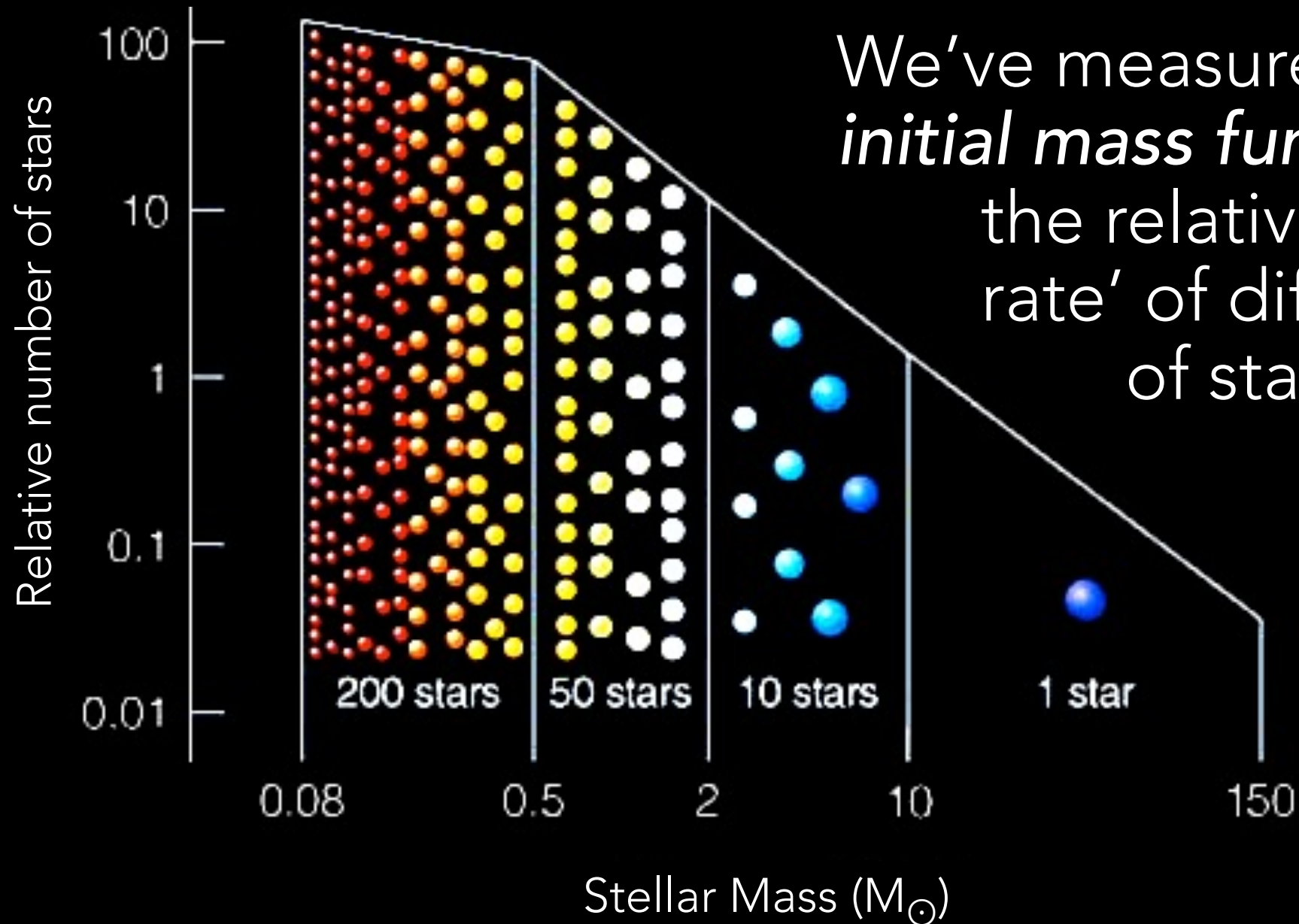


Our star gets big enough that it starts creating its own energy through fusion; it is now a main sequence star.

There's only some dust and debris left over from the formation process.

Fin.

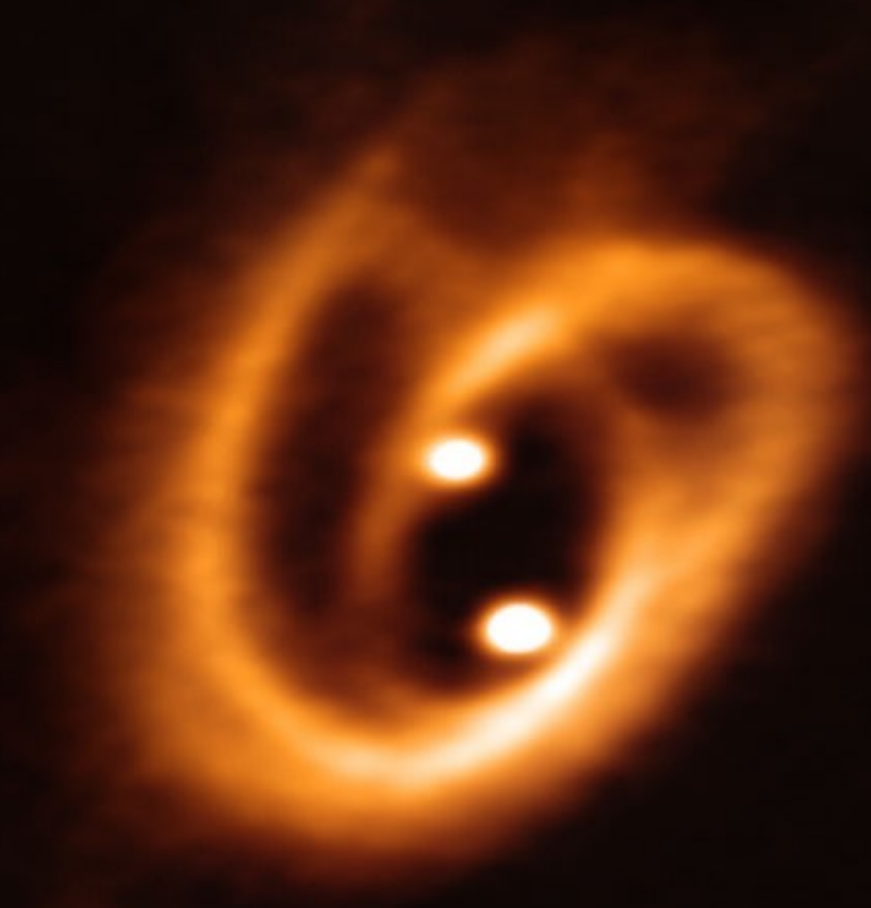
Now that we know how to make one star, what *kind* of stars does a molecular cloud form?

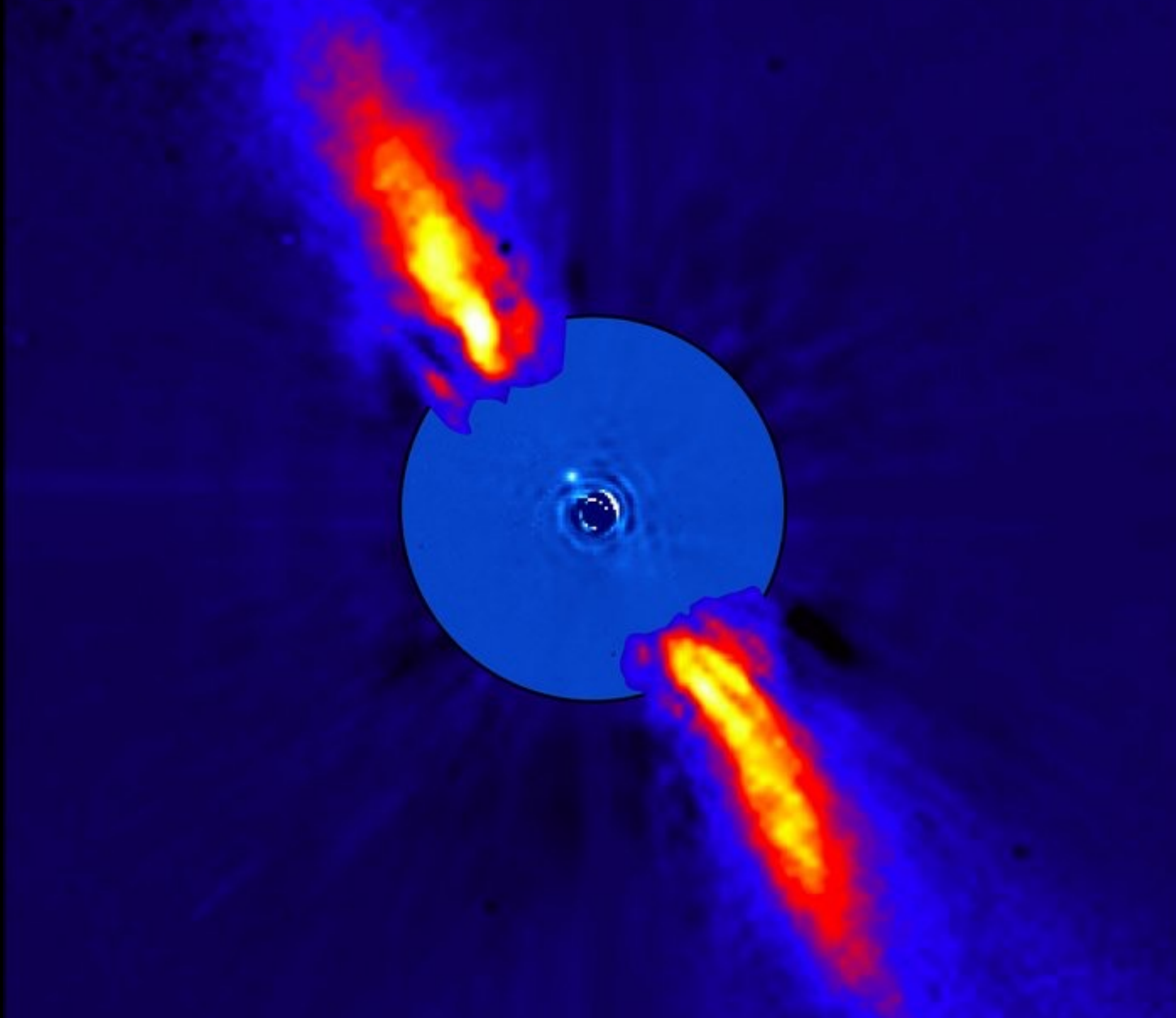


We've measured the
initial mass function of stars:
the relative 'production
rate' of different types
of stars

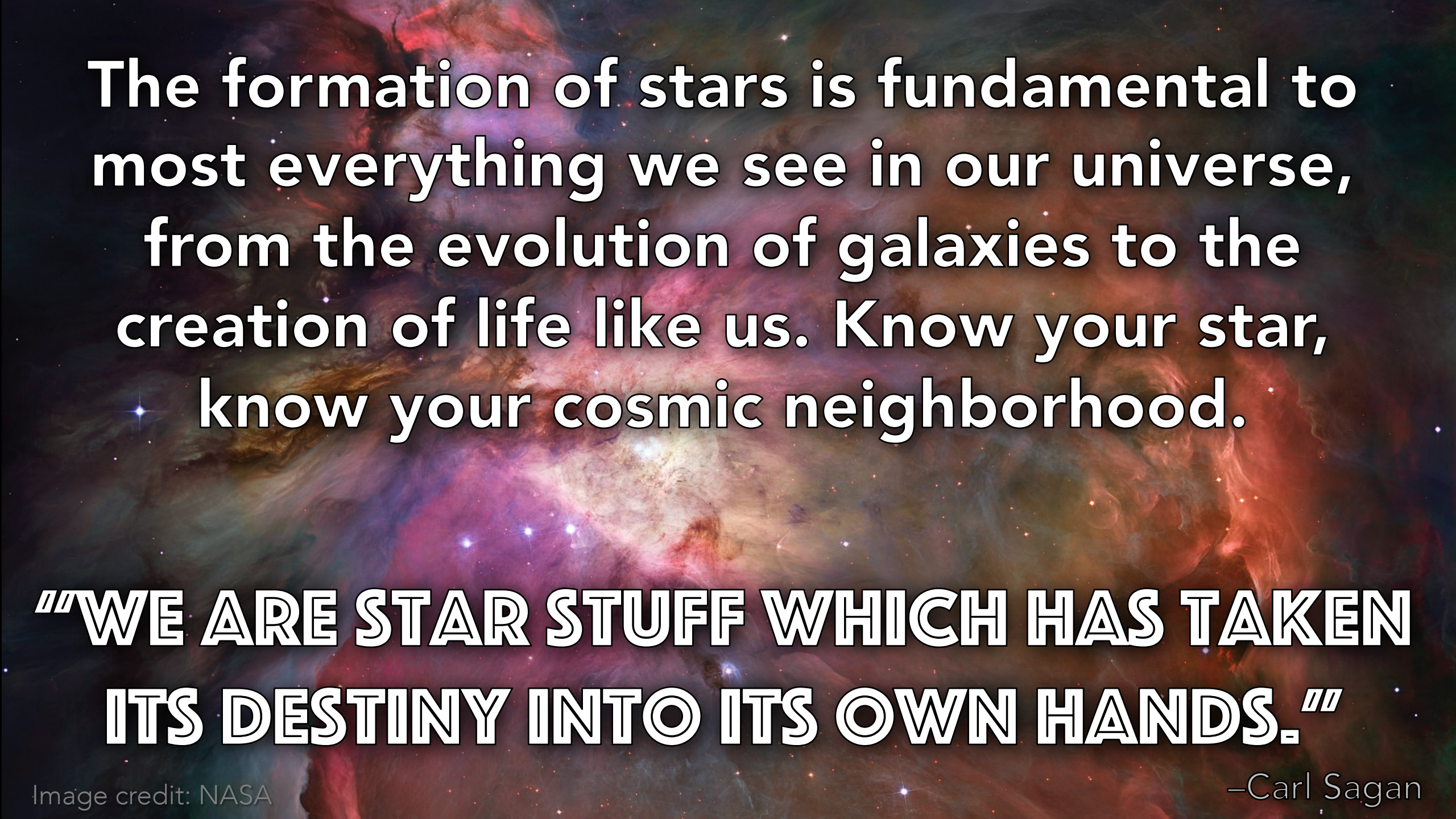
About 50% of all stars orbit another star. These are called *binary stars*.

Some stars orbit two or more other stars!





Based on data to
date, there is an
average of
one planet per
star in the galaxy



The formation of stars is fundamental to most everything we see in our universe, from the evolution of galaxies to the creation of life like us. Know your star, know your cosmic neighborhood.

“WE ARE STAR STUFF WHICH HAS TAKEN ITS DESTINY INTO ITS OWN HANDS.”